Syllabus: *ELEC 548 Neural Signal Processing* (Fall 2015)

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Class Hours: Tuesday, Thursday 9:25-10:40

Course website: The primary location for course information, assignments, and other resources is the course website. Special content available only to students in the class will be hosted as an owlspace resource
http://dsp.rice.edu/courses/elec548
https://owlspace-ccm.rice.edu/portal/site/BIOE-ELEC-548-001-F145

Course Description: The activity of a complex network of billions of interconnected neurons underlies our ability to sense, represent and store the details of experienced life, and enables us to interact with our environment and other organisms. Modern neuroscience techniques enable us to access this activity, and thus to begin to understand the processes whereby individual neurons work together to enable complex behaviors. In order to increase this understanding and to design biomedical systems that might therapeutically interact with neural circuits, advanced statistical signal processing and machine learning approaches are required. This class will cover a range of techniques and their application to basic neuroscience and neural interfaces.

Topics include an introduction to neurobiology and electrophysiology for engineers, point processes, and machine learning techniques including dimensionality reduction, classification/clustering, and time-varying latent variable models. This course is open to students with no prior neurobiology coursework.

Objective: Students should learn the fundamentals of how the activity of neurons represents information within in the brain, how this activity can be monitored experimentally, and how to decode underlying information from the resulting neural data.

Outcome: Students completing the course should be able to:

1. Explain the fundamentals of neural information processing
2. Mathematically model the electrophysiological behavior of neurons
3. Extract information from neural data

Prerequisites: Basic circuits (ELEC 242 or equivalent), Linear algebra (Math 355 or equivalent), Probability (ELEC 303 or equivalent), Signal Processing (ELEC 301 or equivalent). MATLAB will be used for many of the homework assignments so some familiarity with it will be useful.

Textbooks:
Pattern Recognition and Machine Learning by Christopher Bishop **(strongly suggested)**
Theoretical and Computational Neuroscience by Dayan and Abbott
Principles of Neural Science by Kandel, Schwartz, Jessel, Sieglebaum, and Hudspeth

Grading: Six to eight homework assignments (70%) and one final project (30%).

You can be one day (24 hours) late on two HW sets without any penalties. Otherwise there may be a 50% penalty on late HW assignments.

Honor code: You are encouraged to work *with* other students in ELEC 548 on homework problems. Each student, however, must turn in his or her own copy of the solutions. If homework is produced as a team, teammates should be noted on solutions. This year, it is required that each student complete at least 2 assignments by themselves. Even in the case of these two assignments, some discussion is encouraged, but actual solutions should be obtained independently of other students in the course.

Course Outline:

1. **Introduction:**
   1.1 – How is information represented and processing in the brain at the cellular and system level? How can we make sense of the experimental data collected from the brain?
2. **Fundamental Neurobiology:**
   2.1 – The brain, neurons, and glia
   2.2 – Ion channels, membrane potentials, and action potentials
   2.3 – Electrical and chemical synapses
3. **Electrical recording and stimulation technology:**
   3.1 – Local field potentials and single unit recording
4. **Modeling spike trains**
   4.1 - Tuning curves / PSTH
   4.2 - Point processes: Poisson
5. **Basic probabilistic machine learning**
   5.1 - Priors / Likelihood function
   5.2 - Maximum likelihood
6. **Classification**
   6.1 - Linear discriminants
   6.2 - Discrete decoding
7. **Clustering / Mixture models**
   7.1 - PCA
   7.2 - Expectation maximization
   7.3 - Spike sorting
8. **Continuous Decoding**
   8.1 - Linear filter
   8.2 - Kalman filter
9. **Latent variable models**
   9.1 Hidden Markov models for decoding
   9.2 Spike sorting with Gaussian mixtures
   9.3 Particle filters
10. **Spectral estimation (LFP/EEG)**
    10.1 STFT
    10.2 Wavelets and Multitaper techniques

Absence Policies: Class attendance is not required, however students will be responsible for the material covered during lecture. The slides presented during class will be available on the

course website, and it is the responsibility of the student who missed class to work with other students to review any material that is not represented in the online documents.

Students with Disabilities: Any student with a documented disability seeking academic adjustments or accommodations is requested to speak with one of the course instructors during the first two weeks of class. All discussions will remain as confidential as possible. Students with disabilities will need to contact Disability Support Services in the Allen Center.

Information contained in this syllabus, other than the absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructors.